Hanning window was applied with a half-frame overlap. A length-512 FFT of each frame was computed, with the magnitude of the first 257 FFT values displayed vertically, with spectral amplitude values color-coded.

Exercise 5.10.3

Why the specific values of 256 for *N* and 512 for *K*? Another issue is how was the length-512 transform of each length-256 windowed frame computed?

5.12 Discrete-Time Systems

When we developed analog systems, interconnecting the circuit elements provided a natural starting place for constructing useful devices. In discrete-time signal processing, we are not limited by hardware considerations but by what can be constructed in software.

Exercise 5.11.1

One of the first analog systems we described was the amplifier (Amplifiers (Page 27): Amplifiers). We found that implementing an amplifier was difficult in analog systems, requiring an op-amp at least. What is the discrete-time implementation of an amplifier? Is this especially hard or easy?

In fact, we will discover that frequency-domain implementation of systems, wherein we multiply the input signal's Fourier transform by a frequency response, is not only a viable alternative, but also a computationally efficient one. We begin with discussing the underlying mathematical structure of linear, shift-invariant systems, and devise how software filters can be constructed.

5.13 Discrete-Time Systems in the Time-Domain

A discrete-time signal *s(n)* is delayed by n_0 samples when we write $s(n - n_0)$, with $n_0 > 0$. Choosing n_0 to be negative advances the signal along the integers. As opposed to analog delays (Delay (Page 28) : Delay), discrete-time delays can **only** be integer valued. In the frequency domain, delaying a signal corresponds to a linear phase shift of the signal's discrete-time Fourier transform :

$$\left(s(n-n_0) \leftrightarrow e^{-(j2\pi f n_0)} S(e^{j2\pi f})\right) .$$

Linear discrete-time systems have the superposition property.

$$S(a_2 x_1(n) + a_2 x_2(n)) = a_1 S(x_1(n)) + a_2 S(x_2(n))$$

(5.40)